Center Independent Research & Development: JPL IRAD

CCAT Heterodyne Instrument Development (CHAI)

Completed Technology Project (2013 - 2017)

Project Introduction

This work will extend and proof-out the design concept for a high pixel count (128 pixels in 2 bands) submillimeter-wave heterodyne receiver array instrument for the Cerro Chajnantor Atacama Telescope (CCAT). The instrument, now called “CHAI,” the CCAT Heterodyne Array Instrument, is being built by a consortium of institutions led by the University of Cologne and is in its formulation stage. CHAI will require several key technologies uniquely available at JPL, namely the integrated local oscillator distribution scheme and the low-noise amplifier arrays. These subsystems exist as “strawman” concepts at present and consist of a collection of loosely integrated components. If CHAI is to be built successfully, these subsystems must be more tightly integrated together without compromising performance. The integration approach of these key subsystems needs to mature if CHAI is to be implemented.

A key challenge in building a large pixel heterodyne array is efficiently and simultaneously delivering the astronomical signal and local oscillator power to each pixel and conveying the output signal from each pixel. When an array is conceived simply by tightly stacking individual receivers, which is the favored approach for high performance arrays, we soon encounter practical topological difficulties in getting the signals in and out: For CHAI there are 128 rf/local oscillator ports, IF signal outputs, mixer bias supply lines in a unit that is no bigger than 4 inches on a side. The key to our approach is to develop a highly integrated LO distribution network and build it into the array. Many mixer elements are thus pumped by a single source, although the resistive losses in the waveguide hampers the approach for large number of pixels. Second, we will investigate the use of the microwave ribbon cables to draw the signal from the mixer block. Although coaxial cables are used in coherent receiver systems, even small diameter semirigid cables become unwieldy when a small number is involved. The ribbon will convey the signal to the low-noise amplifier array. Several variations of the overall architecture will be evaluated: the differences between single-ended and balanced mixer approaches for a practical instrument will be investigated. While the SUPERCAM instrument has a high degree of integration with the LNA array, the LO and rf beams are still diplexed using a beam splitter approach. Most of the volume of the instrument (~1 cu meter) is simply space occupied by the quasioptical coupling scheme. A more integrated LO subsubsystem could drastically reduce the required volume. In addition, SUPERCAM uses 64 stainless steel coaxial lines to convey the signal from the front-end to the outside. This adds substantial requirements on the cryogenic system and mechanically stresses the focal plane. A ribbon cable to convey the signal from the mixer array to the LNA array and from the LNA array to the outside world is thus a much more elegant approach for implementing a high-pixel count heterodyne array.

After the overall concept design is complete, various subsystems will be evaluated in an affordable manner. (1) For the LO distribution network, the

CCAT Heterodyne Instrument Development

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Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Center Independent Research & Development: JPL IRAD plan is to design, fabricate and evaluate small cells of the LO distribution network operating at various frequencies to establish their feasibility. For a THz distribution network, for example, the final diode would have to be placed next to the mixer, as the high waveguide losses will not allow any significant path lengths. (2) Depending on the application the LNA array may be incorporated into the mixer array (aircraft/ground-based instrument) or be kept at a different thermal environment from the mixer (balloon or space-based instrument). These two different configurations will obviously entail different designs for the integrated heterodyne array. CHAI can potentially use either approach, and for reasons of ease of testing the latter is currently preferred. Approaches to implementing both types will be developed and described. (3) The IF is conveyed from the IF amplifiers (and possibly to them as well) by microwave flexible cables, and although this technology is not novel, their use in an astronomical heterodyne receiver has not been demonstrated. Samples would be designed, procured, and measured in the relevant environment and evaluated for loss, cross talk and survivability through multiple deep cryogenic cycles.

Anticipated Benefits

Supports development of heterodyne detectors for the STO2 funded balloon mission.

Future suborbital and space submillimeter/FIR missions will benefit from this technology. These include balloon missions and possible Probe-class mission such as CALISTO, presented to previous Decadal Survey.

Pollution monitoring

Project Management

Program Manager:

Fred Y Hadaegh

Project Manager:

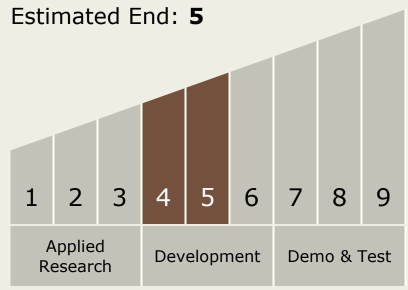
Jonas Zmuidzinas

Principal Investigator:

Jonathan H Kawamura

Technology Maturity (TRL)

Start: **4**
Estimated End: **5**

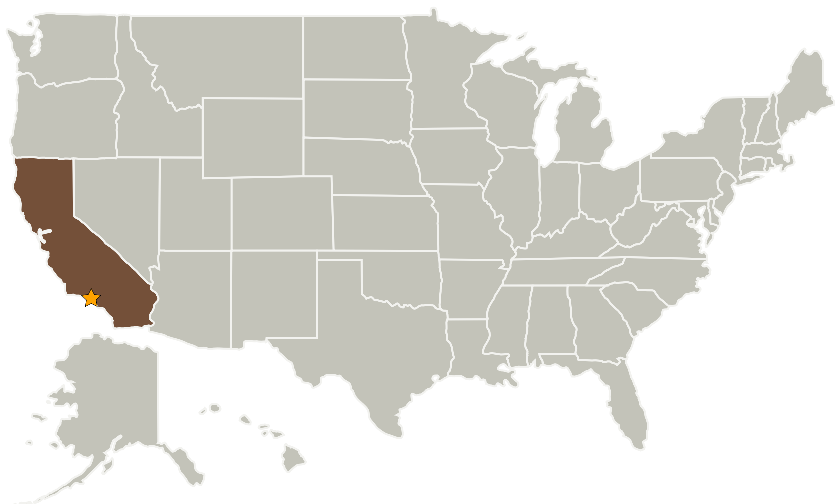


Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.1 Materials
    └ TX12.1.4 Materials for Extreme Environments

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Primary U.S. Work Locations
California